Dryden Flight Research Center Edwards, CA 93523

National Aeronautics and Space Administration July 22, 2004

DFRC Exploration Systems Lessons Learned Workshop Report

July 22, 2004

Lessons from DFRC Workshop July 22, 2004

A lessons learned workshop was held at the Dryden Flight Research Center on July 22,2004. Attendees were as follows:

Daniel Banks	Russ Barber	Al Bowers
Vance Brand	Brad C. Flick	Bart E Henwood
Jeff Jones	Berwin Kock	John A. Marcrum
Jerry McKee	Marta Bohn-Meyer	Chris Naftel
Paul J Reukauf	Michale P. Thomson	Jamie Willhite, Coordinator

DFRC Code T Lessons Learned Workshop RFI Number: BEH -1 July 22, 2004

Category: Program Management

Title & Statement of Lessons Learned: Management & Engineering Experience
People responsible for leading a research development project must have first hand experience in performing that task. Hire from outside the Center or NASA if necessary to find the right person. Management needs to recognize early when there is a mismatch in experience and responsibilities.

Background or Driving Event: Blended Wing Body—it was apparent that lead members lacked experience on how to harness the overall vehicle design process. There were numerous times where it appeared the team could not resolve competing vehicle requirements. Though I do not have hard evidence, I would be surprised to find that the members that led this effort had ever designed a complete vehicle form the floor up of this complexity. There was a mismatch between the experience required and the qualifications of the individuals involved.

DFRC Code T Lessons Learned Workshop RFI BEH -2 July 22, 2004

Category: Program Management

Title & Statement of Lessons Learned: Continuous Operator Input
Mandate assignment of an operator to all major development areas within the program functional elements. Operator must have recent experience and authority to influence the design and concept.

Background or Driving Event: C-17 Engineering Development Program --this program effectively used pilots and loadmasters assigned in the AF program office and nearly all Integrated Product Teams. From an operators viewpoint the design was well done and the C-17 has performed exceptionally in the field.

Detailed Description of Lessons Learned: Many past programs have either ignored operator inputs or allowed for the collection at major design reviews rather than integrating then continuously in the process. The punctuated or periodic approach to inputs only provides a limited view of the implications of certain design features or the limited discovery of overlooked design requirements. This would provide for more stable requirements and update earlier in the program that would significantly reduce the impact to the program.

DFRC Code T Lessons Learned Workshop RFI Number: BEH -3 July 22, 2004

Category: Requirements

Title & Statement of Lessons Learned: Requirements Convergence

Lesson: Convergence of opposing system/operational requirements into a single design solution inherently increases risk to mission success by reducing system operational margins and robustness to unknown variances. The extent to which this risk increases and the mechanism along which it will be manifested may be missed without proper analysis and test.

Background or Driving Event: As a result of budgetary constraints, the Helios program merged its high altitude, solar power objectives with medium altitude, fuel cell power objectives from a two-vehicle demonstration into a single vehicle demonstration. The high altitude vehicle became the starting point for design modifications for the medium altitude vehicle.

Detailed Description of Lessons Learned: The high altitude, solar-powered vehicle was a flexible, lightweight and evenly, span-loaded design predicated on inherent directional control achieved through positive dihedral. The resulting design had a limitation in maximum dihedral, which represented a boundary for pitch phugoid stability. With modification of the high altitude vehicle to accommodate the medium altitude fuel cell objectives the design transformed into a point–loaded configuration with a significant reduction in vehicle robustness to dihedral excursion from wind gust impingement. The lack of real-time simulation analysis failed to recognize the flight control’s dynamic response that sustained excessive dihedral responses that produced an unstable pitch response that then developed a high-energy pendulum effect that exceeded structural strength of the vehicle.

DFRC Code T Lessons Learned Workshop RFI Number: AB -1 July 22, 2004

Category: Requirements, Program Management

Title & Statement of Lessons Learned:

Research v Engineering OR Capability Driven Design v Requirements Driven Design

Detailed Description of Lessons Learned: Research breakthroughs are difficult to predict, to cost, or to schedule (eg: Dick Whitcomb had no requirements or schedule when he developed the area rule, supercritical wings, or winglets in a modern example, or in a classical example Wilbur and Orville Wright in the development of the airplane). Engineering achievement is of a different sort. It can be scheduled, costed, and predicted (eg: Apollo landing on the Moon, Skylab, and Mercury man in space) simply because the technology exists prior to the requirements being made. This is where capability driven design differs from requirements driven design. This is also closely related to technology infusion of new technologies into use.

DFRC Code T Lessons Learned Workshop RFI Number: AB 2 July 22, 2004

Category: Requirements Definition

Title & Statement of Lessons Learned:

Aircraft Requirements v Spacecraft Requirements

Detailed Description of Lessons Learned:

Fundamental differences exist in the physics that drive requirements between aircraft and spacecraft. 1) aircraft use envelope expansion in an incremental fashion, spacecraft are full envelope on the first launch 2) aircraft are recovered for additional upgrade, maintenance and repair, spacecraft are not line repairable/upgradable (exceptions: Shuttle and Hubble) 3) in spacecraft instruments conduct the research, in aircraft the vehicle IS the research 4) as aircraft exceed the weight targets the flight envelope degrades gracefully, in spacecraft excess weight is fatal to mission success

DFRC Code T Lessons Learned Workshop RFI Number: AB 3 July 22, 2004

Category: Safety & Mission Assurance / Risk, Program

Title & Statement of Lessons Learned:
Programmatic Commitment

Detailed Description of Lessons Learned:
Commitment to a program can result in outstanding technical success, despite poor performance in cost and schedule. The X-43A Ship 2 mission success is a shining example of what can be achieved and overcome if the WILL to do so exists!

DFRC Code T Lessons Learned Workshop RFI Number: AB 4 July 22, 2004

Category: System Engineering, Program Management

Title & Statement of Lessons Learned:
Lack of Cost and Schedule Realism

Detailed Description of Lessons Learned:
There appears to be a complete lack of cost and schedule realism in program formulation, and this often results in programmatic failure. X-37 is a prime example. The original NRA for Future-X (now X-37) was a bit more than $300 million (and currently at about $400 million). A single F-22 off the production line (with amortized development costs) is about $240 million. Yet NASA MSFC contracted with Boeing for two (not ONE) X-37s at $300million for both. A complete lack of realism in cost was used on this contract. The schedule is in a like disarray. Failure of this program is imminent because of this.

DFRC Code T Lessons Learned Workshop RFI Number: AB 5 July 22, 2004

Category: S&MA, Risk, System Engineering, Program Management

Title & Statement of Lessons Learned:
Lack of Risk Management Tool Use

Detailed Description of Lessons Learned:
Technical and programmatic risk tools are not used in program formulation. Aerospace Corp published a complexity scale in a report (Aviation Week & Space Technology, 12 Jun 2000, pgs 47-49, "Aerospace Corp. Study Shows limits of Faster-Better-Cheaper", Michael A Dornheim). This was done for a database of 43 spacecraft in 21 subsystem areas by David Bearden (Aerospace Corp). It showed the limits of complexity and cost/schedule on achieving requirements. I was impressed with the study, and adapted it for aircraft, in particular UAVs. I chose six aircraft (five were UAVs) in 18 subsystem areas. Again, the technique showed strong trends with the programs that failed v those that succeeded. Tools such as this should be in wider use during program formulation to improve the odds of success.

DFRC Code T Lessons Learned Workshop RFI Number: AB 6 July 22, 2004

Category: Systems Engineering, Program Management

Title & Statement of Lessons Learned:
Poor Cost & Schedule Formulation

Detailed Description of Lessons Learned:
Insufficient work is performed on schedule and cost in the formulation stages of programs. The Center for System Management has a chart that shows the triangular or Beta distribution (low/optimistic, most likely, & high pessimistic) for cost/schedule and how to estimate most probable cost/time schedule and the reserves required based on the same data. This method is NOT in use by NASA managers in program formulation. The current practice of using the ZERO probability minimum time and minimum cost value results in schedules that have ZERO credibility.

DFRC Code T Lessons Learned Workshop RFI Number: AB 7 July 22, 2004

Category: System Engineering, Mission Ops, Program Management

Title & Statement of Lessons Learned:
Lack of Feasibility Study Work

Detailed Description of Lessons Learned:
Insufficient work on the feasibility and concept of operations ideas in the initial phase of programs results in poor schedule and cost performance. This usually results in program

cancellation. The Center for System Management presents a chart of data compiled by W. Gruhl (NASA HQ) that shows the study phase cost (as a percentage of total development cost) vs Final Overrun Cost (to commitment at the start of development) using data from 25 spacecraft. The trend of shortcuts at the initial phases of development to large overruns (up to nearly 200% overrun) is shown.

DFRC Code T Lessons Learned Workshop RFI Number: AB 8 July 22, 2004

Category: Program Management

Title & Statement of Lessons Learned:
DOD Procurement v NASA Procurement Model in Budgeting

Detailed Description of Lessons Learned:
When DOD runs into funding or technical difficulties, a descope of the production run is often used to contain costs of the program. NASA builds or buys few vehicles, many times single vehicles, and no descope of production can be made without complete failure of the program to achieve mission goals.

DFRC Code T Lessons Learned Workshop RFI Number: BCF-1 July 22, 2004

Category:
Missions and Systems Requirements Definition

Title & Statement of Lessons Learned:
Identification of Risk Acceptability

Lesson: The level of risk acceptable in any programmatic element must be defined and acknowledged at the earliest stages of the program. This drives everything.

Background or Driving Event:
X-34: The vehicle was designed as a single string, unpiloted hypersonic vehicle to be flown over land, near populated areas. When the vehicle neared flight at the testing organization (Dryden), there was no way to prove the robustness or reliability of the single string system to meet safety requirements.

Detailed Description of Lessons Learned:
Involve all parties in the conceptual stages of program planning. Include designers, fabricators, integration and test, operators to make sure that all risks are identified.

DFRC Code T Lessons Learned Workshop RFI Number: BCF-2 July 22, 2004

Category: Program Management

Title & Statement of Lessons Learned:
Defined Roles and Responsibilities of Partners

Background or Driving Event:
Multiple Programs
Good: X-29, X-31, X-43A
Not so Good: X-34, X-37

Detailed Description of Lessons Learned:
Program/Project plans should clearly define the role of every participant and what they are responsible for, to avoid confusion and duplication of efforts. Where responsibilities are handed off between parties, this should be clearly acknowledged.

DFRC Code T Lessons Learned Workshop RFI Number: BCF-3 July 22, 2004

Category: Systems Engineering and Analysis

Title & Statement of Lessons Learned:
"Off The Shelf" Technology

Background or Driving Event:
X-43A Booster Failure

Detailed Description of Lessons Learned:
When a component or technology is used for something other than its intended purpose, it should be treated (reviewed and analyzed) as if it were a new development. The X-43A booster was modified to carry the HXRV, but the margins were poorly understood. When required performance exceeded margins, the mission failed.

Code T Lessons Learned Number JCM –01

Category: Program Management/Mission Operations

Title: Inadequate Planning between vehicle developers and test facilities

Background: Individual contracts awarded to industry for development of aircraft/spacecraft such as X-33, X-34, X-37, etc. etc., and then at some point a competition is held to decide where to test/flight test the vehicle. Vehicle builders often do not follow established standards (e.g. IRIG), or even if they do, the vehicle may not be compatible with selected test facility. This often results in a significant investment in ground facilities (X-33) that are not reusable on future programs.

Lesson Learned: Need to have an integrated development approach that involves early selection/involvement of test facilities. Often, multiple test facilities are required at different locations (e.g. STS/ISS) and require strict configuration control. It is also important to program appropriate levels of funding for technology improvements/operational efficiency so that you are not left with and expensive infrastructure to maintain long term.

Solution for Code T: -Identify test facilities up front -Make investment in new technology and standardize across all facilities -Design all spacecraft (Mars, Moon, etc.) to be compatible with test facilities -Maintain adequate funding to refresh test facilities technology to reduce operational cost

Code T Lessons Learned Number JCM –02

Title: Impossible to estimate costs for this type of program (Space Exploration Enterprise)

Background: We have failed on almost every prior program of this magnitude. We keep trying and failing to estimate costs in an attempt to keep congress happy.

Lessons Learned: Programs of this scale are impossible to estimate costs.

Solution for Code T:

-Convince congress that a more realistic approach would be to estimate sub-projects that would result in technology breakthroughs that are incrementally funded. (pay as you go)

-Do not attempt to go down the road of past examples (STS, ISS) where we knowingly provide low estimates in hopes that the program will be funded and then sit on the hot seat when we can’t deliver. We need to deliver in small increments that we can provide a good cost estimate for with no estimate of the total cost of going to Mars.

Code T Lessons Learned JCN 1

Category: Program Management **Title:** Identify potential adversaries to the program and develop strategies to minimize their impact.

Background: X-33 suffered through attacks from many groups and individuals both inside and outside of NASA. There were numerous GAO audits requested by congressional members from districts that felt threatened by a new low-cost launch vehicle and there were NASA OIG audits throughout the program. Numerous committees were also tasked with assessing the X-33 program. All these investigations and reviews required precious program resources that were not originally budgeted.

Lessons Learned: A new program should be prepared to fend off attacks and include budget, schedule, and people's time for these activities.

Code T Lessons Learned JCN 2

Category: Requirements **Title:** Management of requirements changes

Background: X-33 had new requirements added by upper NASA management late in the program without any additional funding.

Lessons Learned: The impact of requirements changes must be understood at the highest levels of management. Proposed requirements changes must have the corresponding funds identified before it is accepted.

Code T Lessons Learned JCN 3 **Category:** Program Management

Title: Develop end-to-end mission simulations early in the program and update often. Ensure ICD's are coupled with the process.

Background: The human exploration initiative is a complex system of systems and there will be many interactions between the systems that could fall through the cracks.

Lessons Learned: A detailed mission concept needs to be developed early in the program and used to develop the end-to-end mission simulation. All design groups must have access to the simulation and update their part of the simulation as the concept matures.

DFRC Code T Lessons learned Number BK 1 July 22, 04

Category: Program management

Title & Statement of Lessons Learned: Political needs do not necessarily equate achievable technical objectives

Background or driving event: The space shuttle is a prime example. It was politically necessary to promise a vehicle that would fly 100 times/year, carry all US payloads into orbit, provide very low cost transportation, etc. The program was sold on that basis.

The resulting system was dramatically different in capability. Technologically it is uncertain whether those goals could ever have been achieved. The budget drove many compromises. But, the mismatch in what was sold and what was built still is an issue to the agency.

Detailed Description of lessons learned:
Sell what is possible to do Or sell a best effort do
not sign-up to things that cannot be done!

DFRC Code T Lessons learned Number BK 2 July 22, 04

Category: Systems Engineering

Title & Statement of Lessons Learned:
Outstanding processes applied with diligence do not necessarily yield good decisions

Background or driving event:
The Columbia accident, as was also the case with Challenger, was the result of really bad decisions. The Columbia preflight activities followed all NASA processes with rigor. But, by distorting the emphasis to monitoring processes instead of addressing the safety and management fundamentals dealing with accomplishment, the entire management of the program got off track.

The failures of the X-33, X-34, and X-37 in which very rigorous but irrelevant processes were applied obscured the actual state of these projects.

The reality is that, as the agency develops and publishes more and more processes, our performance has gotten worse. That is the history since roughly 1992.

By eliminating the ability to tailor processes, it is virtually assured that the NPR's will become obsolete and will inhibit rather than enhance our agency performance.

Detailed Description of lessons learned:
The NASA civil service complement have become either process authors or process cops. Being a cop is satisfying to the ego. The game of "gotcha" in which some poor soul is found to have fallen short of meeting some possibly irrelevant process or procedure and is duly chastised has become prevalent.

Exploration demands innovation but discipline. If the discipline is directed maintaining the status quo, subjugating thinking for compliance, then both safety and performance will diminish.

DFRC Code T Lessons learned Number BK 3 July 22, 04

Category: Program Mangement

Title & Statement of Lessons Learned:
Success criteria for a project must be clearly defined and understood, from all pertinent aspects, before implementation.

Background or driving event:
Recent X-plane projects (X-33, X-34, X-37) have been failures. Failures in that they either never got to the point of flying, they were (are) also over budget, behind schedule, and could not achieve the overtly stated objective of the program.

But, each of them were also really experiments with contracting methods, experiments in funding projects, experiments in subsidizing industry, experiments in decision making processes. These criteria were never fleshed out in a way to enhance accomplishment of technical objectives. Nobody dealt with the safety and mission success requirements satisfactorily.

Detailed Description of lessons learned:
The definitions of project success must encompass all the essential aspects of a program. Technical, financial, contracting, oversight, and accountability, to mention a few criteria, must be included in the formulation and execution of a project.

It is insufficient to expect a positive outcome if only a partial set of success criteria are used to formulate and execute flight project.

DFRC Code T Lessons learned Number BK 4 July 22, 04

Category: Systems Engineering

Title & Statement of Lessons Learned:
Contractors will know more about the flight article that they designed and built than will the NASA oversight people. A joint industry/government team is a requirement for successful operation of complex flight systems.

Background or driving event:
NASA has conducted many successful X airplane programs. The successful ones were joint efforts with the contractors. The depth of knowledge, scope of information, and experience of people necessary to operate complex systems cannot be present in a small number of civil servants who primarily perform oversight.

The contractor must have a stake in success. This is one of the tenants of Kelly Johnson's Skunk Works philosophy.

NASA today seems intent upon keeping or growing the civil service complement at the expense of contractor involvement. The contractors are portrayed as some kind of untrustworthy villains. That attitude must change.

Detailed Description of lessons learned:
Formulate teams involving contractors and civil service people and functions to accomplish great things.

The inherently government functions of investment management and performance oversight must be preserved. But, implementation and execution of complex flight projects must bring all the best talent to bear on the program.

Code T Lessons Learned (Banks) DB 01

Category: Program Management/Mission and Systems Requirements

Title/Statement: Politics and technology don't mix.

Micromanagement by congress/HQ and politicians/managers who don't fully understand (or at all) the problems and issues.

Background/Event:
X-33 X-34 X-30
NASP X-38 X-37
(in progress)

Description:
Large programs start from the top down. Funding on these programs is predicated on getting buy-in from key congressional members. This in turn means programs (work) going to their districts and for results being promised in time to support their re-election bids. These folks do not understand the process, the technology, the challenges, or anything involved. These programs for the most part inevitably fail. It then appears that NASA failed again and was not able to do the job, but the program as structured was as not doable by any organization.

Code T Lessons Learned (Banks) DB 02

Category: Program Management/Mission and Systems Requirements

Title/Statement:
Not structuring major programs to make more incremental/progressive steps

Background/Event:
X-33 X-30
NASP

Description:
Programs should be structured to make incremental steps and not piling on unknowns and scheduled breakthroughs. Aircraft are built this way. Revolutionary technology is used when it becomes available (mature) and not **scheduled**. Programs that need breakthroughs and revolutionary technology usually fail because the breakthroughs don't show up on schedule and/or budget.

Code T Lessons Learned DB 03

Category: Mission and Systems Requirements

Title/Statement: Ever changing requirements

Background/Event:

Description:
Changing requirements beyond what is really necessary usually results in the demise of programs. At the very least this results in an increase in cost with a concurrent reduction in outcome.

DFRC Code T Lessons Learned Workshop RFI JAM 1 July 22, 2004

Category: Safety & Mission Assurance

Title & Statement of Lessons Learned: Redundant and Reliability for Flight Systems
Redundant and Reliability for flight controls in high cost, high energy, or high public visibility flight programs.

Background or Driving Event:
Persesus A Accident X-34 program funding was cancelled X-40 actuators on the vehicle were designed for use on a missile with a very short life cycle. This was discovered at Dryden after the vehicle was flown once prior to coming to Dryden Flight Research Center.

Detailed Description of Lessons Learned:
Ensure early involvement of Safety & Mission Assurance (SMA) and all other concerns (technical and operational disciplinary) during the conceptual, developmental and implementation phases of the flight programs to ensure redundant and reliability requirements as well as factors of safety are addressed continuously throughout the program.

DFRC Code T Lessons Learned Workshop RFI JAM 2 July 22, 2004

Category: Safety & Mission Assurance

Title & Statement of Lessons Learned: FTS Oversight
Range Safety Office provides Flight Termination Systems (FTS) oversight and continuous involvement throughout the program for unpiloted flight vehicles.

Background or Driving Event:
Theseus Flight 7F6 Mishap Flight Termination System Performance Investigation Report, Dec. 17, 1996. Perseus B Incident (Landing on I-40), Oct. 1, 1999

Detailed Description of Lessons Learned:
In response to Thesus Mishap, a Flight Termination Section was established within the Range Safety Office at Dryden to provide a more structural approach to range safety although range safety was not an issue for this mishap.

DFRC Code T Lessons Learned Workshop RFI Number: JJ -1 July 22, 2004

Category: Program management

Title & Statement of Lessons Learned:
Inadequate level of Authority and Control over Contractor Costs

Background or Driving Event: ISS, X-37, Freedom Program, etc. NASA continually battles program costs many of which result from artificially high contractor costs. The recent flight of Space Ship One, a reusable manned sub-orbital vehicle costing $20M raises the question of why NASA requires $300M for an unmanned vehicle (X-37) that is carried aloft and dropped by a B-52.

During the Space Station Freedom program we encountered a situation that required NASA to add a flight computer to one of the Station Modules. At the time of this request, all required interfaces for this computer had been previously incorporated into the design. This was literally a case of buying the computer, bolting it to the wall, and plugging it in (had the hardware even been built). The prime contractor submitted a $60 M cost impact (in 1993 dollars) for this addition. After a significant amount of arm twisting by the Reston SSFPO this amount was reduced to approximately $6 Million.

A July 8, 2004 article in the Las Vegas Mercury newspaper contained an article on private investor Robert Bigelow’s space development efforts. It cites his attempt to procure a “high-tech valve that would serve as a key component of the life support system”. It states: “American aerospace giants were willing to sell him the valve at costs that ranged from $300,000 to $1 million. Bigelow found and purchased the same valve from a European company. The cost of the identical valve? A mere $5,000.”

Detailed Description of Lessons Learned:
The situation is one that will continue to increase costs. Contractors explain that costs are justified as they are only building a single item rather that the multiple military or commercial

aircraft where they make their profit. However, they fail to take into account the profits that result from items such as the technological advances they acquire as a result of the project and profit from daily operations of programs such as Shuttle and ISS.

Given the budget realities that will always face our efforts, we need to assure that we have greater authority to challenge and control contractor pricing to keep costs as reasonable levels or be given better options on building or procuring items ourselves.

DFRC Code T Lessons Learned Workshop RFI Number:_JJ 2__ July 22, 2004

Category: Program Management, Requirements

Title & Statement of Lessons Learned:

Lack of Consistent Design Review Criteria Throughout the Agency

Background or Driving Event: X-37 There is no standard process that specifies the criteria for design reviews such as SRR, SDR, PDR, and CDR. While there are documents that allegedly define the reviews they are vague and easily misconstrued.

Many organizations have detailed documents specifying in precise detail exactly what is to be covered at each level of review and the level of maturity of that document. For example, the Boeing System Engineering Process Manual (D950-10446-1)

Within NASA, each Center appears to have their own policy towards review content. When this policy is required to be used outside of its normal area, it causes a variety of problems. These can include:

- Required documents omitted from the review
- Insufficient maturity level of documents in the review
- Incomplete coverage of topics required to proceed to the next level of review.

This can impact both cost and schedule by requiring delta reviews, repeated reviews (as with X37) while stacking up documents (that should have been completed) in the queue for the next review.

Detailed Description of Lessons Learned:

The Agency needs to develop a standardized format for design review criteria similar to the Boeing document cited above. While there should be limited flexibility within this document to tailor this process to individual projects, it should be strong enough to enforce the utilization of a single methodology.

DFRC Code T Lessons Learned Workshop RFI Number: JJ -3 July 22, 2004

Category: Program Management, Requirements

Title & Statement of Lessons Learned:
Difficulty infusing new technologies from Research Centers to Operations Centers.

Background or Driving Event:
The NASA Research Centers are continually developing marvelous new technologies, many of which would be potentially valuable, if sufficiently matured, in human space flight programs. Unfortunately a gap exists between our Research Centers and our Operations Centers. The Research Centers generally do not understand the operational methodology and requirements that exist within an Ops Center. Likewise, the Ops centers are generally unaware of the specific projects at the Research Centers and do not have the flexibility to take projects and mature them into a useable flight technology.

The end result is that many of the potentially beneficial technologies developed at the Research Centers reach a TRL-5 and are “thrown over the fence” where they inevitably sit unused.

Detailed Description of Lessons Learned:
The Agency needs to establish a methodology to successfully transition Research Center Technologies for the TRL-5 to the TRL-8 or-9 level. This can be accomplished in a variety of ways. Possibilities include:

- Establishing technology infusion groups at both the Research and Ops Centers that work together to gradually transition the projects through the TRL-6 and –7 levels.
- Establish a funding source specifically geared to the continuation of these technologies once they reach the TRL-5 level.
- Utilization of facilities such as Wallops and Dryden as development sites for appropriate technologies.
- Wallops provides an excellent test bed to mature launch, range operations and mission control technologies prior to transitioning them to human rated programs.
- Both Dryden and Wallops offer a unique blend of research and operational experience that could serve as a template for larger scale technology transition methodologies.

DFRC Code T Lessons Learned Workshop RFI Number: JJ -4 July 22, 2004

Category: Program Management, Requirements

Title & Statement of Lessons Learned:
Problems caused by programmatic and political issues overriding the technical recommendations of system level experts.

Background or Driving Event: ISS In many cases programmatic and political issues have caused improper decisions to be made relative to the technical direction of many areas of our major programs. Decisions frequently are in direct opposition to the technical rationale that exists for the area.

During the shut down activities on the Space Station Freedom in December 1993, it was recommended by both the Level II and Level III propulsion system managers that the ISS program continue the development of the Freedom propulsion modules. Estimated cost was approximately $85M with about a three year window for completion.

Roughly four years later the ISS program decided that a US propulsion capability was required. One of the first options examined was the Freedom Prop system. Due to shut down of production lines the cost to complete this system then stood at over $200M. Several alternatives were investigated with senior management finally deciding on the Interim Control Module (ICM) to be built by the Naval Research Lab by modifying one of their existing upper stage boosters.

This choice was strongly protested by ISS propulsion system management citing numerous technical reasons why the ICM, if ever completed (doubtful) would not be available even remotely close to the agreed upon timeframe (18 months). Senior management explained that this option was chosen because it was the only one not requiring an initial outlay of funds as NASA was going to trade a future Shuttle launch for the ICM.

After an outlay of roughly $250M and several years of effort, the ICM was scrubbed. Interestingly enough, this $250M represented the approximate cost of most of the other options.

Detailed Description of Lessons Learned:
In those instances where technical management/experts feel strongly enough to actively pursue an issue, there needs to a better mechanism to assure that the technical opinions are weighed fairly against the programmatic and political issues.

DFRC Code T Lessons Learned Workshop RFI Number: JWW 1 July 22, 2004

Category: Program Management

Title & Statement of Lessons Learned:
Need to implement successful Multi-Center Government/Contractor Teams

Background or Driving Event: X-40 MSFC/DFRC Boeing Teaming

Detailed Description of Lessons Learned:
The combined Test Force (CTF) Model used at EAFB-FTC is one of the best models I have worked under. The primary contractor, the Air Force, the Civil Servant and support contractors all working together like the spokes of a wheel as a team to accomplish daily flight test missions. This needs to be implemented in multiple locations with teams of civil servants working onsite with contractors and contractors working onsite at the NASA centers. While the contractor usually has the lead role in development, NASA should primarily take the lead role for Responsible Test Organization (RTO), Flight test research and mission execution.

The F-15 ACTIVE program used a similar approach. The contractors performed most of the development with some design input from NASA while DFRC was the Responsible Test Organization that conducted flight test research. The Host program approach used on X-40 was not conducive to a Team Environment.

DFRC Code T Lessons Learned Workshop Number: RB 1 July 22, 2004

Category: Program Management

Title & Statement of Lessons Learned:
Lack of management consistency contributes to undesirable results

Background or Driving Event:
Columbia

Detailed Description of Lessons Learned:
The Lessons Learned Databases from the Challenger, were eroded by a (Faster, Better, Cheaper) paradigm shift that permeated upper levels of Agency management subsequent to Leadership change.

DFRC Code T Lessons Learned Workshop Number: RB 2 July 22, 2004

Category: Safety and Mission Assurance

Title & Statement of Lessons Learned:
Hazard Tracking

Background or Driving Event:
Columbia Accident

Detailed Description of Lessons Learned:
The CAIB identified the fact that more than 5,000 potential hazards were being tracked by the shuttle program prior to the Columbia accident. That sheer number of hazards would seem to be overwhelming to any risk management process. If one group was tasked to review this number of hazards, and they could review 1 hazard every 20 minutes, it would take them 208 days to complete.

This issue should be addressed to determine a realistic solution toward a manageable total number of mission risks.

DFRC Code T Lessons Learned Workshop Number: RB 3 July 22, 2004

Category: Safety and Mission Assurance

Title & Statement of Lessons Learned:
Flight/Mission Contingency Planning

Background or Driving Event:
Columbia Accident

Detailed Description of Lessons Learned:
Current Agency Safety and Mission Assurance processes do not presently define a process for contingency review as part of the airworthiness process. Perhaps, contingency planning should become a new dimension of the safety and mission assurance process. Schemes could be developed that would visualize contingency options to responsible management, for example red, yellow, and green levels of contingency. A red contingency might be one that would result in very serious consequences, a yellow contingency would result in serious consequences and a green would have acceptable consequences. Having to define and categorize available contingencies before a mission might stimulate useful mission planning dialog before

an incident occurs. Preflight debate about those portions of a mission where no contingency exists might in fact identify some far out action that should at least be considered.

DFRC Code T Lessons Learned Workshop RFI Number: MPT -1 July 22, 2004

Category: Program Management/Requirements

Title & Statement of Lessons Learned:
X-34 Funding V. Requirements

Background or Driving Event:
The X-34 was established under the faster, better, cheaper philosophy. During the program, the requirements changed such that loss of vehicle was unacceptable. This cascaded to higher costs and eventual program cancellation.

Detailed Description of Lessons Learned:
The X-34 program was scoped to fit program funding profile and not vehicle requirements.

DFRC Code T Lessons Learned Workshop RFI Number: MPT -2 July 22, 2004

Category: Mission Operations and Ground Support

Title & Statement of Lessons Learned:
Retaining Experienced Staff

Background or Driving Event:
The X-43A 2nd flight. Fuel system problems developed on B-52 mothership prior to launch. Aircrew and technicians on ground were able to trouble shoot real-time to solve problems and continue with mission, leading to the successful launch of X-43A #2.

Detailed Description of Lessons Learned:
Sustaining an experienced technical staff is important when using aging systems.

DFRC Code T Lessons Learned Workshop Number: MPT #3 July 22, 2004

Category: Program Management

Title & Statement of Lessons Learned:
Inadequate Funding

Background or Driving Event:
The X-33 program was inadequately funded from the start, yet both contractor and NASA accepted the contract knowing this.

Detailed Description of Lessons Learned:
Do not accept programs, which are known to have inadequate funding to meet objectives and requirements as laid out.

DFRC Code T Lessons Learned Workshop Number: MPT -4 July 22, 2004

Category: Mission Operations

Title & Statement of Lessons Learned:
Electronic Spares

Background or Driving Event:
Electronic (digital) spare parts have limited shelf life and become obsolete quickly.

Detailed Description of Lessons Learned:
Systems should be designed with enough interface flexibility to incorporate "plug and play" newer electronic spares as required.

DFRC Code T Lessons Learned Workshop RFI Number: PJR -1 July 22, 2004

Category: Safety & Mission Assurance

Title & Statement of Lessons Learned:
Civil Servant vs. Contractor responsibilities during development and test of one-of-a-kind vehicles.

Background or Driving Event:
X-43C Performance Based Contract Type NASA Independent Program Assessment Office (IPAO) Contract Review

Detailed Description of Lessons Learned:
The X-43A Project indicated that full cooperation and integration of Civil Servant (CS) and Contractor workforce maximizes the probability of mission success for these kind of nonproduction research vehicles. The contract on X-43A was changed from an incentive fee type to a fixed fee type to accommodate this philosophy.

NASA headquarters dictated that the contract on X-43C must be an incentive based contract. The Project office determined that no hands on work could be performed by CS personnel because the incentive fees clauses might be invalidated. Thus this contracting mechanism essentially negates the ability of NASA to share responsibility for development and operations. Thus, CS personnel are relegated to reviewing contractor plans and designs, watching the contractor operation, and attending PowerPoint briefings to understand the probability of mission success and airworthiness of the resulting vehicle. This oversight may be enough for highly experienced CS personnel to gain a full technical understanding of the system but still precludes finding deficiencies that are only found by hands-on testing and maintenance of the vehicle. Less experienced CS personnel would probably not catch items overlooked by the contractor under the oversight or insight scenario. Thus NASA cannot provide credible oversight or insight under the current incentive fee contracting mechanisms.

The IPAO reviewed the contracting mechanism for X-43C and did not agree with the above assertions. Their position was that the Contractor should have proper incentives and the Government should keep their hands off. Unfortunately, if the vehicle is lost because of an oversight by the contractor, the Government does not have their needs fulfilled and the bulk of the project cost is expended except for some small amount of fee.

The lesson learned is that contracting mechanisms should not impede either the contractor or CS personnel from bringing the best capabilities to the project, be it in design, analysis, testing, or maintenance. The full integration of Contractor and CS efforts maximizes the probability of mission success and provides the Government with a mechanism to maintain a highly skilled workforce in all areas of the development process.

DFRC Code T Lessons Learned Workshop RFI Number: PJR -2 July 22, 2004

Category: Safety & Mission Assurance

Title & Statement of Lessons Learned:
Center Roles and Responsibilities

Background or Driving Event:
X-43C Project negotiations with DFRC

Detailed Description of Lessons Learned:
Every project that comes to DFRC from outside the Center insist on negotiating responsibilities for ground safety, flight safety, range safety, and flight operations. These negotiations generally occur after the Project Formulation stage so it is impossible for DFRC to create credible cost and workforce estimates during the planning effort since the scope of work is not yet determined in detail. Each Center should have generally agreed upon, non-negotiable responsibilities so that the scope of their effort will be similar in most projects they are involved in. These NASA level agreements would form a basis for credible cost estimates early in the project formulation and allow standardized work breakdown structures.

DFRC Code T Lessons Learned Workshop No: VB -1 July 22, 2004

Category: Requirements

Title & Statement of Lessons Learned:
The need for an X-plane must be understood and related to a top-level vision. The technology result must support the vision.

Background or Driving Event:
For example, the X-37 had an unclear, unstated need and relevance with regard to national space mission. The X-34 started as an orbital vehicle program and after several goals revisions, appeared to be only a means to test the Fastrac engine.

DFRC Code T Lessons Learned Workshop No: VB -2 July 22, 2004

Category: Program Management

Title & Statement of Lessons Learned:
You cannot write a requirements document and throw it over the fence with a bag of money and expect success. An X-vehicle requires significant customer (government) technical involvement. Government must be a smart buyer. Government must have an oversight and insight role to assure that sound engineering management and review processes are in place.

Background or Driving Event:
For example, in the case of the DC-XA, the Government believed that the contractor was capable and trusted; hence, the project office was very small, and it appeared not to be staffed to have great insight into contractor flight test activities. After the DC-XA crash, the Lessons Learned effort suggested that the Government ensure that effective maintenance checks were in place and monitor the contractor to make sure that unwise shortcuts were not taken.

Another example: On both X-33 and X-37, NASA has behaved more like the Department of Defense by leaving responsibility for program success in the hands of the contractor. However, DoD generally has potential production contracts following vehicle development, and NASA X-vehicles are often one-of-a-kind. Therefore, a contractor may not have the same motivation for NASA X-vehicles as with DoD vehicles.

DFRC Code T Lessons Learned Workshop No: VB -3 July 22, 2004

Category: Program Management

Title & Statement of Lessons Learned
You have to do something substantial in 2 to 4 years; otherwise you lose the attention of stakeholders (including Congress) and top management. If a program is longer than 4 years, plan to have early hardware demonstrations (flights) to show progress, and strive to meet early milestones. This will help to gain continuous support for the total project. Trade studies and viewgraphs are not substantial products.

Background or Driving Event:
The federal funding process and politicians demand quick results in order to continue funding support. Programs generally must produce visible results (as opposed to trade studies and documents) to receive support. Examples: The Space Launch Initiative, which might have produced X-vehicles, did not develop much flight hardware and eventually failed. Although both the X-33 and X-34 produced hardware, their costs escalated, the propellant tanks or engines were not ready on time, and in some cases the technology was not ready.

DFRC Code T Lessons Learned Workshop No: VB -4 July 22, 2004

Category: Program Management

Title & Statement of Lessons Learned
Project Management must balance getting product out the door versus preoccupation with process.

Background or Driving Event:
Example: X-37 had a very large program office where there was a lot of “process-related” activity (reviews, studies, and other paper products) in comparison to the amount of flight hardware and flights produced.

DFRC Code T Lessons Learned Workshop No: VB -5 July 22, 2004

Category: Requirements

Title & Statement of Lessons Learned
Never start a program or project in an under funded state. Typically, actual costs eventually will exceed estimated costs, or the money available will evolve to being less than anticipated as the development progresses.

Background Driving Event:
Space Exploration Initiative. X-37

DFRC Code T Lessons Learned Workshop No: VB -6 July 22, 2004

Category: Program Management

Title & Statement of Lessons Learned
Do not use the cooperative agreement as a contracting instrument in large vehicle developments. When actual costs exceed a certain level, there is no incentive for the contractor to continue

Background Driving Event: X-33

DFRC Code T Lessons Learned Workshop No: VB -7 July 22, 2004

Category: Requirements

After setting the goals and requirements, make sure that the approach allows the goals to be accomplished with some confidence. For example, the X-34's single-string flight control system approach did not allow the program to meet its reliability and safety goals with confidence.

Background or Driving Event:
The X-34 was designed with a single-string flight control system, which was a high-risk approach for an experimental vehicle program that was so expensive. After the failure of the Mars observers, NASA became more risk-averse, and wanted to add redundancies to X-34. At that stage in the lifecycle, it was very complicated and expensive to do so.